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PRATYLENCHUS PENETRANS

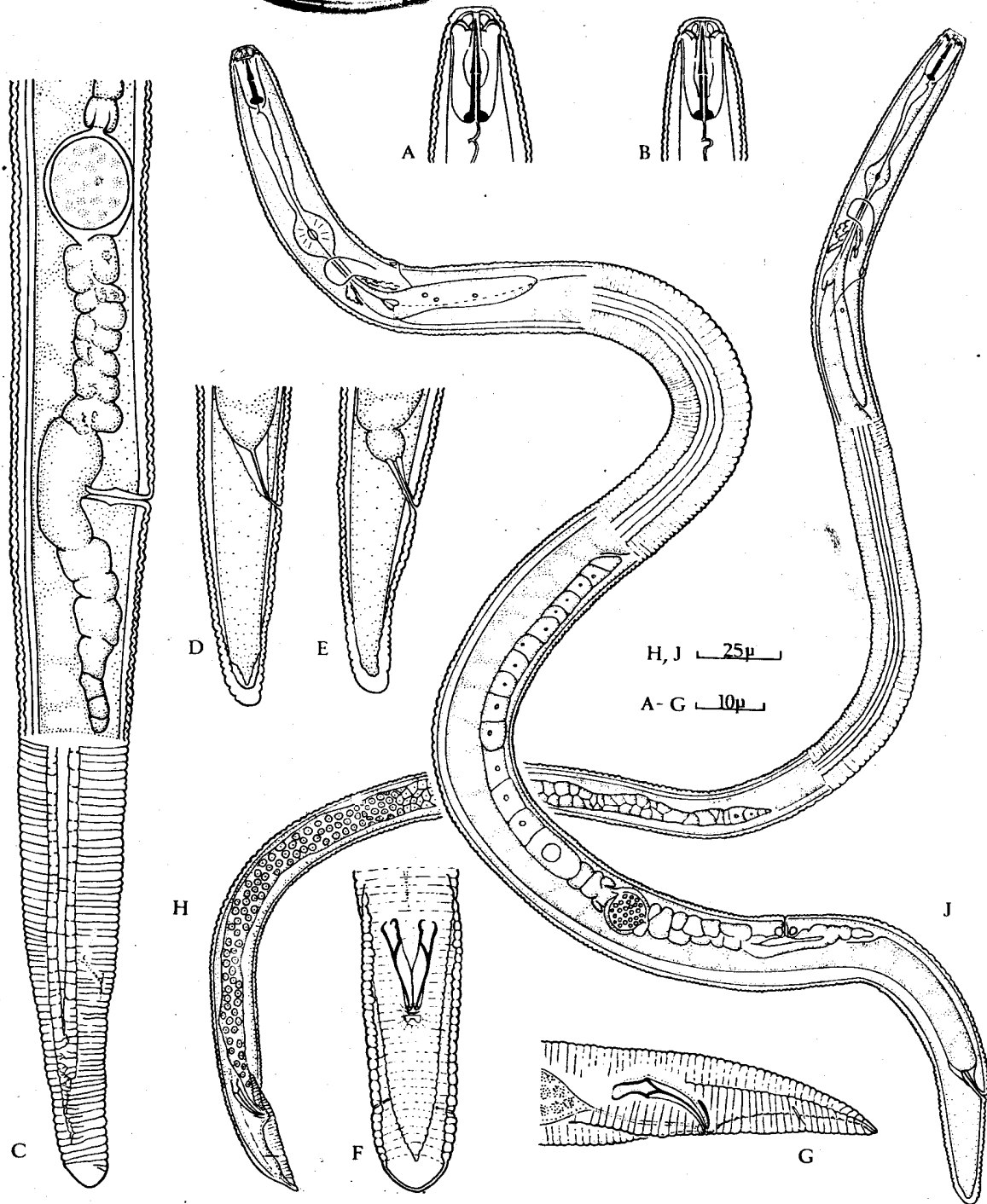


Fig. 1 *Pratylenchus penetrans*. A. Female head. B. Male head. C. Female vulva region and tail. D, E. Female tail tips. F, G. Male tails in ventral view (F) and lateral view (G). H. Male. J. Female. (A-G, topotypes, courtesy M.W. Allen.)

***Pratylenchus penetrans* (Cobb, 1917) Chitwood & Oteifa, 1952.**

Syn. (from Loof, 1960). *Tylenchus gulosus* Kühn, 1890; Fischer, 1894; *Tylenchus penetrans* Cobb, 1917 ♂; *Tylenchus pratensis* in Steiner, 1927; Bovien, 1927; Steiner, 1932; *Tylenchus (Chitinotylenchus) penetrans* in Rahm, 1928, 1929 (somewhat doubtful); *Anguillulina pratensis* in Goodey, 1932 & 1933; W. Schneider, 1939; *Pratylenchus pratensis* in Filipjev and Schuurmans Stekhoven, 1941; Goodey, 1951; *Pratylenchus penetrans* in Sher & Allen, 1953; possibly *Tylenchus pratensis* de Man, 1881; 1884 ♂, nec 1880, 1884 ♀; nec *Tylenchus penetrans* Cobb, 1917 ♀.

MEASUREMENTS (partly after Loof, 1960, and Sher & Allen, 1953) ♀♀: L = 343-811 μ; a = 19-32; b = 5.3-7.9; c = 15-24; V = 75-84%; spear = 15-17 μ; excretory pore from head = 74-101 μ.

Neotype ♀: L = 530 μ; a = 26; b = 5.8; c = 16; V = 4181^{3.7}.

♂♂: L = 305-574 μ; a = 23-34; b = 5.4-7.3; c = 16-22; T = 36-58%; spear = 13-16 μ; spicules = 14-17 μ; gubernaculum = 3.9-4.2 μ; excretory pore from head = 66-79 μ.

DESCRIPTION Female: Body moderately slender, almost straight when killed by gentle heat. Cuticular annulation fine. Lateral field normally with four incisures, outer bands may be partly areolate, central field sometimes with oblique striae near vulva, becoming areolate behind vulva, not extending to tail tip. Lip region slightly set off, low, flat in front, with rounded outer margins, 3 annules. Head with strong, conspicuous skeleton. Basal knobs of spear broadly rounded, sometimes cupped anteriorly. Oesophagus overlapping intestine ventrally in a lobe about 1.5 body-widths long. Excretory pore about opposite oesophago-intestinal junction with hemizonid occupying about two body annules immediately in front of it. Post-uterine sac short, undifferentiated, about 1 or 1.5 vulval body-widths long. Spermatheca spherical, or nearly so. Tail generally rounded, tip smooth, with 15–27 annules on ventral surface.

Male: Common. Slightly smaller than female, but similar in form. Lateral field with four incisures ending on the bursa, occasionally with oblique lines in central field near mid body. Spicules slender, with well-marked manubria and ventrally arcuate shafts, 14–17 μ long; gubernaculum simple, 3.9–4.2 μ long. Tail about twice as long as anal body diameter; bursa irregularly crenate along edge, enveloping tail tip.

For variations see Roman and Hirschmann, 1969.

TYPE HOST AND LOCALITY Greenhouse soil, Rhinebeck, New York, USA.

SYSTEMATIC POSITION Tylenchida: Tylenchoidea: Pratylenchidae: Pratylenchinae: *Pratylenchus* Filipjev, 1936.

DISTRIBUTION AND HOSTS *P. penetrans* is recorded on over 350 hosts mainly in temperate areas in Europe, Australia, Canada, Egypt, India, Japan, New Zealand, Peru, Philippines, Rhodesia, Russia, South Africa, Tunisia and USA. It is a major pest of fruit and conifer nurseries in many areas, and causes serious losses in tobacco (Canada and N.E. United States), apple and cherry orchards (N.E. United States and parts of Europe), and roses (Canada and parts of Europe). It is frequently associated with "soil sickness" and some forms of "replant disease" (Mountain & Boyce, 1958; Hoestra, 1968) as well as decreasing cold hardiness of cherry trees (Edgerton & Parker, 1958). It may be a serious pest locally of a number of crops, e.g. narcissi in the Scilly Isles off the S.W. tip of England, and in the Netherlands. It is commoner in horticultural than in arable soils in Europe but is often found in arable soils in North America.

BIOLOGY AND LIFE-HISTORY *P. penetrans* is an obligate plant parasite with a simple life cycle. Reproduction is sexual (Hung & Jenkins, 1969; Thistlethwayte, 1970): after fertilization, females lay eggs singly in roots or soil. The first moult occurs in the egg; the second-stage larva hatches from the egg and moults three more times, between intervals of feeding, to become adult. The complete life cycle takes 30 to 86 days, depending on temperature, and is shortest at 30°C, although fewer eggs are laid at this temperature than at 20 or 24°C (Mamiya, 1971).

The main overwintering stages of *P. penetrans* are adults and 4th stage larvae (Miller, 1968; Kable & Mai, 1968b) although many eggs survive winter in roots (Dunn, 1972). All larval stages and adults can invade roots, but more 4th stage larvae and adults of both sexes penetrate than do 2nd and 3rd stage larvae (Sontirat & Chapman, 1970; Townshend, 1972). *P. penetrans* is most often found in sandy soils (Kleyburg & Oostenbrink, 1959). Adults and larvae migrate further in coarse than in fine-textured soil models and best when sufficient water has drained to leave 8 to 12% of the soil volume occupied by air (Townshend & Webber, 1971). More penetrate roots in a sandy loam (coarse textured soil) than in a silt loam or a loam (fine textured soil) (Townshend, 1972).

P. penetrans is distributed in infested soil and on rooted nursery stock and may spread in surface drainage or irrigation water (Faulkner & Bolander, 1970). It reproduces best between pH 5.2 and 6.4 on vetch or lucerne plants (Morgan & McLean, 1968; Willis, 1972). Host plants grown in unfavourable conditions, e.g. in soils deficient in potassium, nitrogen or calcium (Shafiee & Jenkins, 1962) or at low light levels or following defoliation (Dolliver, 1961) are more heavily infested and severely damaged by *P. penetrans* than vigorous crops. Numbers of *P. penetrans* in the soil of many crops are most in late summer and early autumn and fewest in late spring and early summer: they are often associated with "flushes" of root growth of the host plant (Di Edwardo, 1961; Ferris, 1967; Miller, R. E. *et al.*, 1963). Up to 65% die in winter after a spring-sown annual crop (Olthof, 1971). *P. penetrans* can survive high CO₂ concentrations (Specht & Walker, 1969), but survives a shorter time in wet than in dry soil (Kable & Mai, 1968a). The behaviour of two separate isolates on tobacco suggests that different races or strains exist (Olthof, 1968).

HOST PARASITE RELATIONS *P. penetrans* is essentially a parasite of the root cortex, but in later stages of attack it penetrates and damages the vascular tissues of some hosts (Acedo & Rohde, 1971; Mamiya, 1970) and has been recorded attacking begonia and sunflower stems (Seinhorst, 1954*). In all hosts, cells in the cortex are broken and cavities formed: rarely, affected tissues do not discolour (Troll & Rohde, 1966) but in most hosts discolouration, especially of the inner cortex and adjoining endodermis, occurs sooner or later (Townshend, 1963a and b). Peach roots are discoloured within 9 hr of inoculation and, within 24 hr, a necrotic lesion is visible on the affected root (Mountain & Patrick, 1959). Similar lesions develop in many other hosts, but more slowly (Oyekan *et al.*, 1972; Pitcher *et al.*, 1960). Above-ground parts of affected plants are usually stunted and chlorotic, with early death of older leaves and, in woody plants die-back of twigs: root systems are greatly diminished (Caveness, 1957; Hoestra & Oostenbrink, 1962; Stone, 1953*; Townshend, 1962a and b). The numbers required to stunt hosts vary with the host, soil and climate, from about 50/litre soil for lily to about 2000/litre for potatoes in peat or loam (Dowe, 1971; Oostenbrink, 1972).

The effect of *P. penetrans* on hosts may be enhanced by interaction with root-infecting fungi: e.g. *Aphanomyces euteiches* on peas (Oyekan & Mitchell, 1972); *Cylindrocarpon radicum* on oats and bulbs (Hastings & Boshier, 1938; Sloomweg, 1956); *Fusarium oxysporum* on lucerne, peas and birdsfoot trefoil (Edmunds & Mai, 1966a; Lin, 1968; Oyekan & Mitchell, 1971; Seinhorst & Kuniyasu, 1971; Willis & Thompson, 1971); *F. roseum* on carnations (Martinović & Gručić, 1970); *Trichoderma viride* on lucerne (Edmunds & Mai, 1966b) and *Verticillium albo-atrum* and/or *V. dahliae* on eggplant, peppermint, peppers, potatoes, strawberries and tomato (Bergeson, 1963; Miller & Edgington, 1962; Miller *et al.*, 1967; Mountain & McKeen, 1965; Olthof & Reyes, 1969; Rich & Miller, 1964). Usually the disease caused by both fungus and nematode is worse as the number of nematodes or level of fungal inoculum increases (Conroy *et al.*, 1972) but pepper plants attacked by *P. penetrans* may be protected thereby against *V. dahliae* (Anon, 1970). *P. penetrans* reproduces faster in *Verticillium*-infected roots of some hosts than in uninfected (Mountain & McKeen, 1962), but slower in others (Conroy *et al.*, 1972) and may reproduce in the same host infected with *Verticillium* faster or slower than when it is uninfected depending on the nutrients available to the plant (Dwinell, 1967; Dwinell & Sinclair, 1967). The breakdown of resistance of peas to *F. oxysporum* f. *pisi* when inoculated with

* *P. penetrans*, not *P. pratensis*—*in litt.*



Fig. 2 A. *P. penetrans* infected strawberry plant on the left, uninfected on the right. B. Small strawberry root with *P. penetrans* in cortex. C. Lesions on adventitious root of strawberry, with a small feeder root girdled at the base following attack by *P. penetrans*. D. Coalescence of six original lesions into a single large lesion on a *P. penetrans* infected strawberry root. (All photos courtesy J.L. Townshend, Canadian Journal of Botany (A) and Canadian Journal of Plant Science (B, C & D).)

P. penetrans but not when wounded with a sterile needle suggests that the nematode does more than just wound the host to let the fungus in (Oyekan & Mitchell, 1971). In many cases controlling *P. penetrans* also decreases incidence of fungal disease (Biehn *et al.*, 1971; Miller & Hawkins, 1967).

CONTROL Satisfactory control of *P. penetrans* in the field is achieved by fumigating the soil before planting with dichloropropene-dichloropropane or 1,3-dichloropropene products at rates from 170 to 600 litres/ha, depending on formulation and method of application (D'Herde & Coolen, 1966; Ferris, 1968; Maggenti *et al.*, 1967; Mai & Parker, 1967; Mai *et al.*, 1970; Mamiya, 1969; Morgan, 1964; Wuyts *et al.*, 1971). Spring application increases leaf chlorine in tobacco (Elliott & Mountain, 1963) and causes phytotoxic symptoms in maize (Edmunds *et al.*, 1967) and in roots of *Cryptomeria* seedlings (Mamiya, 1969). Formulations of dichloropropenes with methyl isothiocyanate or propargyl bromide sometimes control *P. penetrans* better than the dichloropropenes alone (McKee & Mountain, 1967; Mai *et al.*, 1970; Taylor *et al.*, 1970). Other fumigants that successfully control *P. penetrans* are chloropicrin (Apt & Gould, 1961), methyl bromide (Bassus, 1969; Peterson, 1970), dazomet (Bassus, 1969; Thompson & Willis, 1970) and Vapam (Decker, 1961; Knierem, 1964; Seinhorst & Knoppin, 1960). DBCP and EDB have given variable results. The effects of some fumigants can last for 2 or 3 years (Miller & Hawkins, 1969; Taylor *et al.*, 1970).

Granular aldicarb at 3 to 11 kg a.i./ha gave good control of *P. penetrans* in a number of crops and prophos at 11.2 kg/ha also controlled it well. Phorate at 13 to 33 kg/ha alone or mixed with thionazin at 9 kg/ha; fensulfothion at 11 kg/ha; methomyl at 11 kg/ha; carbofuran at 4.5 to 17 kg/ha and phenamiphos at 4.5 to 8 kg/ha also controlled it well (Cetas, 1971; Elliott *et al.*, 1972; Hart & Maggenti, 1970; Hawkins & Miller, 1971; Heide, 1971; Krusberg, 1971; Maggenti *et al.*, 1970; Rhoades, 1968; Thompson & Willis, 1970).

Du Pont 1410 (*S*-methyl 1-(dimethyl carbamoyl)-*N*-[(methyl carbamoyl)oxy]thioformimidate) sprayed on plants at rates of 4 to 10 kg/ha one to four times decreased numbers of *P. penetrans* in the roots as effectively as soil treatment (Abawi & Mai, 1971; Stokes & Laughlin, 1970).

Chemical dips control *P. penetrans* in various plant organs. Easter lily bulbs soaked in 0.5% phorate for 15 minutes had fewest *P. penetrans* compared with a number of treatments but did not give increased yields (Hart *et al.*, 1967). *P. penetrans* was eradicated when leatherleaf fern transplants were dipped in 800 ppm of fensulfothion, phenamiphos or prophos for 30 minutes (Stokes & Laughlin, 1970).

Hot water treatment also eradicates *P. penetrans* from roots of nursery plants of apple (45.5 or 46°C for 15 or 30 min, depending on pre-treatment), quince (45.5°C for 12 or 15 min), strawberry (48°C for 10 min) and *Juniperus virginiana* (40°C for 10 min, then 52°C for 2 min) (Anon, 1971; Boshier & Orchard, 1963; Goheen & McGrew, 1954; Peterson, 1964; Scotto La Massese, 1966). Some crop management practices such as winter fallowing (Olthof, 1971), summer fallowing (Mountain & Elliott, 1963) or, in orchards, herbicide spraying to prevent weed establishment (Marks *et al.*, 1972) keep *P. penetrans* populations low. Mulching (Miller & Waggoner, 1963) or incorporation in the soil of several organic amendments (Miller & Edgington, 1962; Morgan & Collins, 1964; Walker *et al.*, 1967) decrease *P. penetrans* populations possibly by encouraging nematophagous fungi (Pääsuke, 1962), actinomycetes or bacteria with toxic metabolites (Walker *et al.*, 1966) or toxic breakdown products in plant residues, such as butyric acid (Sayre *et al.*, 1965). Growing two species of *Tagetes*, *Helenium* hybrids, a *Gaillardia* hybrid or *Eriophyllum caespitosum* decrease soil populations of *P. penetrans* (Hijink & Winoto Suatmadji, 1967; Oostenbrink *et al.*, 1957) sufficiently to allow good growth of succeeding crops.

LITERATURE CITED

- Abawi, G.S. & Mai, W.F., 1971. *Pl. Dis. Repr* 55, 617-620 [H.A.(B) 41, No. 237]. Acedo, J.R. & Rohde, R.A., 1971. *J. Nematol.* 3, 62-68 [H.A.(B) 40, No. 671]. Anon., 1970. *Res. Rep. for 1969 Canada Dep. Agric.* pp. 99-107. Anon., 1971. *Res. Rep. for 1970 Canada Dep. Agric.* pp. 351-359. Bassus, W., 1969. *Arch. PflSchutz* 5, 431-444 [H.A.(B) 40, No. 206]. Bergeson, G.B., 1963. *Phytopathology* 53, 1164-1166 [H.A. 33, No. 991]. Biehn, W.L. et al., 1971. *Pl. Dis. Repr* 55, 968-971 [H.A.(B) 41, No. 572]. Bosher, J.E. & Orchard, W.R., 1963. *Can. J. Pl. Sci.* 43, 195-199 [H.A. 38, No. 338]. Caviness, F.E., 1957. *Pl. Dis. Repr* 41, 1058 [H.A. 26, No. 437c]. Cetas, R.C., 1971. *Phytopathology* 61, 887 [H.A.(B) 41, No. 244]. Chitwood, B.G. & Oteifa, B.A., 1952. *Ann. Rev. Microbiol.* 6, 151-184 [H.A. 21, No. 335a]. Conroy, J.J. et al., 1972. *Phytopathology* 62, 362-366 [H.A.(B) 41, No. 87]. Decker, H., 1961. *NachrBl. dt. PflSchutzdienst* 15, 64 [H.A. 32, No. 2098]. D'Herde, J. & Coolen, W., 1966. *Meded. Rijksfac. LandbWet. Gent* 31, 639-649 [H.A. 38, No. 2893]. Di Edwardo, A.A., 1961. *Pl. Dis. Repr* 45, 67-71 [H.A. 31, No. 530]. Dolliver, J.S., 1961. *Phytopathology* 51, 364-367 [H.A. 31, No. 531]. Dowe, A., 1971. *NachrBl. PflSchutzdienst DDR* 25, 133-136 [H.A.(B) 41, No. 835]. Dunn, R.A., 1972. *J. Nematol.* 4, 221-222. Dwinell, L.D., 1967. *Diss. Abstr.* 28, 15B-16B [H.A. 37, No. 2405]. Dwinell, L.D. & Sinclair, W.A., 1967. *Phytopathology* 57, 810 [H.A. 37, No. 1360]. Edgerton, L.J. & Parker, K.G., 1958. *Proc. Am. Soc. hort. Sci.* 72, 134-138 [H.A. 29, No. 715]. Edmunds, J.E. & Mai, W.F., 1966a & b. *Phytopathology* 56, (a) 1132-1135; (b) 1320-1321 [H.A. 36 (a) No. 1648; (b) No. 1579]. Edmunds, J.E. et al., 1967. *Pl. Dis. Repr* 51, 15-19 [H.A. 37, No. 1406]. Elliott, J.M. & Mountain, W.B., 1963. *Can. J. Soil. Sci.* 43, 18-26 [H.A. 33, No. 1157]. Elliott, J.M. et al., 1972. *Can. J. Pl. Sci.* 52, 1-11 [H.A.(B) 41, No. 861]. Faulkner, L.R. & Bolander, W.J., 1970. *J. Nematol.* 2, 362-367 [H.A.(B) 40, No. 458]. Ferris, J.M., 1967. *J. Econ. Ent.* 60, 1708-1714 [H.A. 37, No. 3528]. Ferris, J.M., 1968. *Pl. Dis. Repr* 52, 519-521 [H.A. 38, No. 6391]. Goheen, A.C. & McGrew, J.R., 1954. *Pl. Dis. Repr* 38, 818-826 [H.A. 23, No. 479]. Hart, W.H. & Maggenti, A.R., 1970. *Pl. Dis. Repr* 54, 1016-1017 [H.A.(B) 40, No. 739]. Hart, W.H. et al., 1967. *Pl. Dis. Repr* 51, 978-980 [H.A. 38, No. 2896]. Hastings, R.J. & Bosher, J.E., 1938. *Can. J. Res., Sect. C* 16, 225-229 [H.A. 7, No. 90]. Hawkins, A. & Miller, P.M., 1971. *Am. Potato J.* 48, 21-25. Heide, A., 1971. *NachrBl. PflSchutzdienst DDR* 25, 119-123 [H.A.(B) 41, No. 866]. Hijink, M.J. & Winoto Suatmadji, R., 1967. *Neth. J. Pl. Path.* 73, 71-82 [H.A. 37, No. 603]. Hoestra, H., 1968. *Meded. Landb. Hogesch. Wageningen* 68 (13), 105 pp. [H.A. 38, No. 6126]. Hoestra, H. & Oostenbrink, M., 1962. *Neth. J. agric. Sci.* 10, 286-296 [H.A. 32, No. 1938]. Hung, C.L. & Jenkins, W.R., 1969. *J. Nematol.* 1, 352-356 [H.A.(B) 39, No. 938]. Kable, P.F. & Mai, W.F., 1968a & b. *Nematologica* 14, (a) 101-122; (b) 150-151 [H.A. 37 (a) No. 3492; (b) No. 3493]. Kleyburg, P. & Oostenbrink, M., 1959. *Neth. J. agric. Sci.* 7, 327-343 [H.A. 30, No. 147]. Knierim, J.A., 1964. *Q. Bull. Mich. St. Univ. agric. Exp. Stn* 46, 527-532 [H.A. 35, No. 426]. Krusberg, L.R., 1971. *Pl. Dis. Repr* 55, 276-279 [H.A.(B) 40, No. 748]. Lin, Y., 1968. *Pl. Prot. Bull. Taiwan* 10, 29-40 [H.A.(B) 39, No. 671]. Loof, P.A.A., 1960. *Tijdschr. PZiekt.* 66, 29-90 [H.A. 30, No. 1012]. McKeen, C.D. & Mountain, W.B., 1967. *Can. J. Plant Sci.* 47, 1-10. Maggenti, A.R. et al., 1967. *Pl. Dis. Repr* 51, 549-552 [H.A. 37, No. 1413]. Maggenti, A.R. et al., 1970. *Pl. Dis. Repr* 54, 1012-1014 [H.A.(B) 40, No. 752]. Mai, W.F. & Parker, K.G., 1967. *Pl. Dis. Repr* 51, 398-401 [H.A. 37, No. 1414]. Mai, W.F. et al., 1970. *Pl. Dis. Repr* 54, 792-795 [H.A.(B) 40, No. 230]. Mamiya, Y., 1969. *Bull. Govt. Forest Expt. Stn (Japan)* No. 220. Mamiya, Y., 1970. *J. Jap. Forest Soc.* 52, 41-50 [H.A.(B) 40, No. 288]. Mamiya, Y., 1971. *Nematologica* 17, 82-92 [H.A.(B) 40, No. 946]. Marks, C.F. et al., 1972. *Phytopathology* 62, 776. Martinović, M. & Gručić, G., 1970. *7th Int. Cong. Pl. Prot. Paris* 190 [H.A.(B) 41, No. 409]. Miller, P.M., 1968. *Pl. Dis. Repr* 52, 768-772 [H.A. 38, No. 4017]. Miller, P.M. & Edgington, L.V., 1962. *Pl. Dis. Repr* 46, 745-747 [H.A. 32, No. 2131]. Miller, P.M. & Hawkins, A., 1967. *Am. Potato J.* 44, 339. Miller, P.M. & Hawkins, A., 1969. *Am. Potato J.* 46, 387-397 [H.A.(B) 40, No. 757]. Miller, P.M. & Waggoner, P.E., 1963. *Pl. Soil* 18, 45-52 [H.A. 33, No. 2816]. Miller, P.M. et al., 1967. *Am. Potato J.* 44, 316-323 [H.A. 38, No. 2904]. Miller, R.E., et al., 1963. *Phytopathology* 53, 313-315 [H.A. 33, No. 526]. Morgan, G.T., 1964. *Can. J. Pl. Sci.* 44, 170-174 [H.A. 34, No. 1044]. Morgan, G.T. & Collins, W.B., 1964. *Can. J. Pl. Sci.* 44, 272-275 [H.A. 34, No. 223]. Morgan, G.T. & McLean, A.A., 1968. *Nematologica* 14, 311-312 [H.A. 38, No. 1228]. Mountain, W.B. & Boyce, H.R., 1958. *Can. J. Bot.* 36, 135-151 [H.A. 27, No. 20b]. Mountain, W.B. & Elliott, J.M., 1963. *Can. J. Pl. Sci.* 42, 642-645 [H.A. 32, No. 2133]. Mountain, W.B. & McKeen, C.D., 1962. *Nematologica* 7, 261-266 [H.A. 32, No. 1532]. Mountain, W.B. & McKeen, C.D., 1965. *Can. J. Bot.* 43, 619-624 [H.A. 35, No. 1108]. Mountain, W.B. & Patrick, Z.A., 1959. *Can. J. Bot.* 37, 459-470 [H.A. 28, No. 27]. Olthof, T.H.A., 1968. *Nematologica* 14, 482-488 [H.A. 38, No. 2864]. Olthof, T.H.A., 1971. *Nematologica* 17, 453-459 [H.A.(B) 41, No. 560]. Olthof, T.H.A. & Reyes, A.A., 1969. *J. Nematol.* 1, 21-22 [H.A.(B) 39, No. 64]. Oostenbrink, M., 1972. In: J.M. Webster [Editor], *Economic Nematology*. London: Academic Press. pp. 497-514 [H.A.(B) 41, No. 1175]. Oostenbrink, M. et al., 1957. *Nematologica* 2 (Suppl.) 424-433 [H.A. 26, No. 570p]. Oyekan, P.O. & Mitchell, J.E., 1971. *Pl. Dis. Repr* 55, 1032-1035 [H.A.(B) 41, No. 410]. Oyekan, P.O. & Mitchell, J.E., 1972. *Phytopathology* 62, 369-373 [H.A.(B) 41, No. 1055]. Oyekan, P.O. et al., 1972. *J. Nematol.* 4, 32-35 [H.A.(B) 41, No. 816]. Pääsuke, M., 1962. *Acta Agric. scand.* 12, 135-147 [H.A. 32, No. 1373]. Peterson, G.W., 1964. *Pl. Dis. Repr* 48, 862 [H.A. 35, No. 459]. Peterson, G.W., 1970. *Pl. Dis. Repr* 54, 572-575 [H.A.(B) 40, No. 240]. Pitcher, R.S. et al., 1960. *Nematologica* 5, 309-314 [H.A. 31, No. 432]. Rhoades, H.L., 1968. *Pl. Dis. Repr* 52, 383-385 [H.A. 38, No. 6418]. Rich, S. & Miller, P.M., 1964. *Pl. Dis. Repr* 48, 246-248 [H.A. 34, No. 880]. Roman, J. & Hirschmann, H., 1969. *J. Nematol.* 1, 363-386 [H.A.(B) 39, No. 734]. Sayre, R.M. et al., 1965. *Nematologica* 11, 263-268 [H.A. 35, No. 756]. Scotto La Massese, C., 1966. *Meded. Rijksf. Landbouwwet. Gent* 31, 617-638 [H.A. 37, No. 1420]. Seinhorst, J.W., 1954. *Inst. PZiekt. Ond. Ann. Rep.* 1953, 114-117. Seinhorst, J.W. & Kuniyasu, K., 1971. *Nematologica* 17, 444-452 [H.A.(B) 41, No. 414]. Shafiee, M.F. & Jenkins, W.R., 1962. *Pl. Dis. Repr* 46, 472-475 [H.A. 32, No. 2324]. Sher, S.A. & Allen, M.W., 1953. *Univ. Calif. Publs. Zool.* 57, 441-470 [H.A. 22, No. 417]. Sloopweg, A.F.G., 1956. *Nematologica* 1, 192-200 [H.A. 25, No. 266d]. Sontirat, S. & Chapman, R.A., 1970. *J. Nematol.* 2, 270-271 [H.A.(B) 40, No. 179]. Specht, C.H. & Walker, J.T., 1969. *J. Nematol.* 1, 27-28 [H.A.(B) 39, No. 188]. Stokes, D.E. & Laughlin, C.W., 1970. *Pl. Dis. Repr* 54, 287-288 [H.A.(B) 39, No. 1189]. Stone, L.E.W., 1953. *Ann. appl. Biol.* 40, 742-749 [H.A. 22, No. 301a]. Taylor, J.B. et al., 1970. *N.Z. J. Sci.* 13, 591-602 [H.A.(B) 40, No. 500]. Thistlethwayte, B., 1970. *J. Nematol.* 2, 101-105 [H.A.(B) 39, No. 1220]. Thompson, L.S. & Willis, C.B., 1970. *Can. J. Pl. Sci.* 50, 577-581 [H.A.(B) 40, No. 250]. Townshend, J.L., 1962a & b. *Can. J. Pl. Sci.* 42, (a) 314-322; (b) 728-736 [H.A. 32, (a) No. 302; (b) No. 1970]. Townshend, J.L., 1963a & b. *Can. J. Pl. Sci.* 43, (a) 70-74; (b) 75-78 [H.A. 32, (a) No. 2934; (b) No. 2935]. Townshend, J.L., 1972. *Nematologica* 18, 201-212. Townshend, J.L. & Webber, L.R., 1971. *Nematologica* 17, 47-57 [H.A.(B) 40, No. 960]. Troll, J. & Rohde, R.A., 1966. *Phytopathology* 56, 995-998 [H.A. 36, No. 1673]. Walker, J.T. et al., 1966. *Can. J. Microbiol.* 12, 347-351 [H.A. 37, No. 659]. Walker, J.T. et al., 1967. *Pl. Dis. Repr* 51, 1021-1024 [H.A. 38, No. 2921]. Willis, C.B., 1972. *J. Nematol.* 4, 291-295. Willis, C.B. & Thompson, L.S., 1971. *Proc. Can. phytopath. Soc.* 37, 29 [H.A.(B) 41, No. 751]. Wuyts, F. et al., 1971. *Meded. fac. LandbWet. Rijksuniv. Gent* 36, 1027-1041.

* Apt, W.J. & Gould, C.J., 1961. *Pl. Dis. Repr* 45, 290-295 [H.A. 31, No. 319].

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